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Aegean and Black Sea 2006 Expedition

I, Robot, Can Do That!

(adapted from the 2005 Lost City Expedition)

Focus
Underwater robotic vehicles for scientific exploration

Grade Level
9-12 (Life Science/Earth Science)

Focus Question
How can underwater robots be used to assist scientific explorations?

Learning Objectives
Students will be able to describe and contrast at least three types of underwater robots used for scientific exploration.

Students will be able to discuss the advantages and disadvantages of using underwater robots in scientific exploration.

Given a specific exploration task, students will be able to identify robotic vehicles best suited to carry out this task.

Materials
None

Audio/Visual Materials
None

Teaching Time
One 45-minute class period, plus time for student research

Seating Arrangement
Six groups of students

Maximum Number of Students
30

Key Words
ABE
ROPOS
Remotely Operated Vehicle
Hercules
Tiburon
RCV-150
Robot

Background Information
The geographic region surrounding the Aegean and Black Seas has been the stage for many spectacular performances in Earth's geologic and human history. Human activities on the region's stage began during Paleolithic times; artifacts discovered near Istanbul are believed to be at least 100,000 years old. Well-known Aegean cultures include the Minoans (ca 2,600 – 1,450 BC), Mycenaeans (ca 1,600 – 1,100 BC), Ancient Greeks (776 – 323 BC), and Hellenistic Greeks (323 – 146 BC). Istanbul—"the only city that spans two continents"—has been a crossroads of travel and trade for more than 26 centuries. Mariners have traveled the Aegean and Black Seas since Neolithic ("Stone Age" times; 6,500 – 3,200 BC), probably for a combination of purposes, including trading, exploration, and warfare.

Interactions between these cultures and many others were often violent and destructive. So, too, were interactions with geological processes. Some of these processes are directly related to the same forces that are believed to have caused the breakup of Pangaea (see "Volcanoes, below). One of the most dramatic and destructive events was the eruption of a volcano in a small group of Aegean islands called Thera (also known as Santorini), sometime between 1,650 and 1,450 BC. Estimated to be four times more powerful than the Krakatoa volcano of 1883, the eruption left a crater 18 miles in diameter, spewed volcanic ash throughout the Eastern Mediterranean, and may have resulted in global climactic impacts. Accompanied by earthquakes and a tsunami, the volcano destroyed human settlements, fleets of ships, and may have contributed to the collapse of the Minoan civilization on the island of Crete, 110 km to the south. On Thera, the largest of the Santorini islands, the ancient city of Akrotiri was completely buried beneath the ash. Excavation of the city began in 1967, and is ongoing. The Bronze Age eruption of the Santorini volcano was by no means its last. In fact, the volcano erupted at least 12 times between 197 BC and 1950 and most geologists agree that a violent eruption will happen again.

Interactions with other geological processes may have been equally disastrous. In 1997, geologists William Ryan and Walter Pitman published a theory in which the Black Sea was inundated around 5,600 BC by flood waters from the Mediterranean passing through the Straits of Bosporus at Istanbul. Such a deluge, if it occurred, would have been disastrous for human settlements along the Black Sea shoreline and might have provided an origin for accounts of cataclysmic floods in Christianity and other cultures. Subsequent research has neither proved nor disproved the Black Sea deluge theory, but in 2000, Robert Ballard discovered remains of a wooden structure that may have been part of an ancient seaport 95 meters below the surface of the Black Sea (see http://news.nationalgeographic.com/news/2000/12/122800blacksea.html). This may be one of the best places in the world to look for remains of ancient civilizations, because the deep waters of the Black Sea contain almost no oxygen, so the biological organisms that normally attack such relics cannot live in this environment.

Finding well-preserved archaeological sites, studying ancient maritime trade, and exploring the history of the Theran volcano are the primary goals of the Ocean Explorer Aegean and Black Sea 2006 Expedition. Explorations to pursue these goals are divided into two segments. In the first segment, side-scan sonar, subbottom profiling, and multibeam bathymetric technology are used to survey selected portions of the Aegean, Black, and Eastern Mediterranean Seas. The second segment uses remotely operated vehicles (ROVs) for direct visual observation of promising sites located during the first segment. Increasingly, robotic vehicles are becoming essential tools of modern ocean exploration. In this lesson, students will investigate underwater robots and how ocean explorers use them.

Learning Procedure

1. To prepare for this lesson:
   - Review the background essays for the Aegean and Black Sea 2006 Expedition at http://oceanexplorer.noaa.gov/explorations/06blacksea/; and
   - Review the Ocean Explorer Web pages on underwater robotic vehicles, indexed at http://oceanexplorer.noaa.gov/technology/subs/subs.html.

   If students do not have access to the internet, make copies of relevant materials on underwater robotic vehicles from the Web site referenced above.

2. Briefly introduce the Aegean and Black Sea 2006 Expedition emphasizing ways in which underwater robots will be used by the Expedition. You may want to show video clips

from some of the sites referenced in Step 1 to supplement this discussion.

3. Tell students that their assignment is to investigate underwater robots that can be used to perform various tasks that support scientific exploration of the deep ocean. Assign one of the following robots to each student group, and provide each group with a copy of "Underwater Robot Capability Survey:"
   Autonomous Benthic Explorer (ABE)
   Hercules
   Remotely Operated Platform for Ocean Science (ROPOS)
   General Purpose Remotely Operated Vehicles (ROVs)
   RCV-150
   Tiburon

   You may want to direct students to the Ocean Explorer Web pages on underwater robotic vehicles (see above). If students do not have access to the internet, provide copies of the relevant materials to each group.

4. Have each student group present a brief oral report of the capabilities of their assigned robot. The following points should be included:

Autonomous Benthic Explorer (ABE)
- capable of operating to depths up to 5,000 meters
- autonomous vehicle; no tether to support ship
- tools: video cameras, conductivity and temperature sensors, depth recorder, magnetometer, sonar, wax core sampler, navigation system
- developed to monitor underwater areas over a long period of time
- follows instructions programmed prior to launch; data are not available until robot is recovered
- operates independently during missions, but requires technicians and engineers for maintenance, as well as data managers to retrieve information stored in computer memory

Remotely Operated Platform for Ocean Science (ROPOS)
- capable of operating to depths up to 5,000 meters
- 5,500 m of electrical-optical cable tether
- tools: two digital video cameras; two manipulator arms that can be fitted with different sampling tools (stainless steel jaws, manipulator feedback sensors, rope cutters, snap hooks, core tubes); variable-speed suction sampler and rotating sampling tray; sonar; telemetry system
- can also be outfitted with up to eight custom-designed tools such as a hot-fluid sampler, chemical scanner, tubeworm stainer, rock-coring drill, rock-cutting chainsaw, laser-illuminated, range gated camera, and downward-looking digital scanning sonar
- wide variety of observation tools provides scientists with exceptional flexibility so they can quickly respond to new and unexpected discoveries
- a "typical" dive requires at least four people (and sometimes more): the "Hot Seat" scientist, pilot, manipulator operator, and data/event logger

General Purpose Remotely Operated Vehicles (ROVs)
- depth capability varies
- operated by one or more persons aboard a surface vessel
- linked to the ship by a group of cables that carry electrical signals back and forth between the operator and the vehicle
- tools: most are equipped with at least a video camera and lights
- additional equipment may include a still camera, a manipulator or cutting arm, water samplers, and instruments that measure water clarity, light penetration, and temperature
- also used for educational programs at aquaria and to link to scientific expeditions live via the internet
- range in size from that of a bread box to a

small truck
- often kept aboard vessels doing submersible operations for safety, and so the ROV can take the place of the submersible when it cannot be used because of weather or maintenance problems
- can also be used to investigate questionable dive sites before a submersible is deployed to reduce risk to the submersibles and their pilots

Hercules

- capable of operating to depths of 4,000 meters
- pilots operate Hercules via a long fiber-optic cable
- designed primarily to study and recover artifacts from ancient shipwrecks
- tools: High-Definition (HD) video camera; pair of still cameras to accurately measure the depth and area of the research site and to create "mosaics;" sensors for measuring pressure, water temperature, oxygen concentration, and salinity
- hydraulic thrusters—propellers in fixed ducts—control the ROV's movements
- yellow flotation package makes Hercules slightly buoyant in seawater
- components that are not in pressure housings are immersed in mineral oil, which does not compress significantly under pressure
- operates in tandem with tow sled "Argus"
- 30-meter (100 foot) tether connects Hercules to Argus
- Argus carries an HD video camera similar to the one on Hercules, as well as large lights that illuminate the area around Hercules
- generally operates 24 hours a day while at sea, different teams called "watches" take turns operating the vehicle
- six watch-standers on each watch:
  - Watch Leader makes sure that the scientific goals of the dive are being addressed
  - Pilot operates Hercules, controlling its thrusters, manipulator arms, and other functions
  - Engineer controls the winch that moves Argus up and down, as well as Argus' thrusters and other functions, and assists the Pilot
  - Navigator monitors the work being done and the relative positions of the vehicles and ship and communicates with the ship's crew to coordinate ship movements
  - Video and Data watch-standers record and document all the data that the vehicles send up from the deep
- Little Hercules replaces Hercules for some missions; Little Hercules has no arms or tools, only gathers video images

Tiburon (ROV)

- capable of operating to depths 4,000 meters
- controlled from a special control room on board its tender vessel, the R/V Western Flyer.
- tether contains electrical wires and fiber-optic strands
- electrical thrusters and manipulators, rather than hydraulic systems, allow vehicle to move quietly through the water, causing less disturbance to animals being observed
- variable buoyancy system allows the vehicle to float motionless in the water without the constant use of the thrusters
- lower half of the vehicle is a modular toolsled, which can be exchanged with other toolsleds to carry out specific missions: benthic (or bottom) toolsled has an extra manipulator arm and extensive sample-carrying space for geological and biological samples; "midwater" toolsled used to explore the biology of open ocean creatures; rock coring toolsled has been used to take oriented rock cores from the sea floor

RCV-150

- capable of operating to depths of 914 m
- tethered to support ship via a double armored electro-optical umbilical
- tools: color video camera, 1500 watts of lighting, micro conductivity/temperature/depth sensor, sonar, manipulator with a six inch cutoff wheel

- controlled by a single pilot from a control console located in the tracking room of the support ship
- small size compared to a submersible allows ROV to have high maneuverability; can get close to the bottom and allow the cameras to peer under ledges and into nooks and crannies
- much easier to launch and recover than a manned submersible so it can be used at night while the submersible is being serviced
- primary data collected is in the form of video
- has been used to conduct surveys of bottom-fish in Hawai'i
- In the event of a submersible emergency with one of the Pisces submersibles in water depths less than 3000 ft, the first action after notifying rescue assets would be to deploy the RCV-150 to evaluate the nature of the emergency and if entangled, try to free the submersible with the radial cutter

5. Tell students that you are going to describe a series of missions for which an underwater robot is needed. After they hear each mission description, each group should decide whether their robot is capable of the mission, and then discuss which of the candidate robots is best suited for the job.

   Read each of the following mission descriptions:

   (a) We are planning an expedition to study an unexplored area of the Arctic Ocean with a maximum depth of 3,000 meters. We are particularly interested in geological formations, and want to collect rock cores and samples of biological organisms that may be living on these formations.
   [ROPOS and Tiburon can be fitted with a rock-coring drill and biological sampling equipment.]

   (b) As part of the ongoing study of the Santorini volcano, we want to survey selected underwater areas around the islands that may show evidence of sunken cities. This will require a robot that can travel back and forth across a survey area, maintaining a distance of about 5 meters from the bottom, with continuous depth recordings and video images taken every 10 meters.
   [Several robots have the capability to do this work, but ABE is best suited for this type of survey since it can operate independently while humans do other work.]

   (c) We are studying fish communities around deep water coral reefs off the coast of Florida (depth 500 – 700 m). We need video records of fish species in a variety of habitats, particularly under coral ledges near the bottom.
   [RCV-150 and some General Purpose ROVs could do this work. RCV-150 has been used specifically for fish surveys, and its small size allows it to work close to the bottom and record images under ledges.]

   (d) We are developing an educational program for our city aquarium, and want to show some of the capabilities of underwater robots. What kind of robot would be most practical for this purpose?
   [A small General Purpose Remotely Operated Vehicle would be most cost effective.]

   (e) Our expedition is studying the linkages between pelagic (mid-water) and benthic (bottom) communities associated with a hydrothermal vent in the Gulf of Mexico (depth is approximately 2,500 meters). We want to collect biological samples from both areas, as well as geological samples (including rock cores) from the benthic areas.
   [ROPOS and Tiburon are capable of collecting the benthic and rock core samples. Tiburon also has a dedicated toolsled specifically for studying midwater organisms.]

(f) We are exploring the wreck of a Spanish galleon that lies in a deep canyon 3,000 meters below the surface. We need a complete, detailed photographic survey of the area around the ship, and also want to be able to recover artifacts that may be discovered.
[Hercules was designed specifically for the study of ancient shipwrecks and recovery of artifacts, and is capable of high-definition photographic surveys.]

(g) A Pisces submersible has become tangled in the rigging of a sunken freighter in 1,500 feet of water. We need a robot to survey the situation and cut the rigging to free the submersible.
[All of the robots could respond to this emergency – if they were in the immediate area and had the necessary cutting attachments available. RCV-150 is specifically designed to support Pisces operations and would most likely be carried as part of emergency response equipment on support vessels.]

(h) We are exploring a series of underwater caves approximately 300 meters deep. The entrances to some of these caves is only about 300 cm square. We need video images of the interior of these caves to plan further explorations.
[General Purpose Remotely Operated Vehicles can be as small as a bread box, and could provide the video images needed for this work.]

(i) Our research team is studying an unexplored chain of underwater volcanoes. We want to sample geological formations as well as biological communities, but won't know exactly what types of samples will be needed until we can see the area. Depths in our study area will be between 1,500 and 4,500 meters.
[ROPOS can be fitted with a wide variety of observation tools that could give these scientists the flexibility they need to respond to new and unexpected discoveries]

(j) Our scientific team needs to monitor the water temperature around a newly erupting underwater volcano two miles below the surface of the ocean. We need samples taken every hour for a month.
[ABE is the only robot in the group capable of autonomous operations and long-term monitoring.]

(k) We are studying the biological communities of a deepwater (1,000 – 2,000 meters depth) coral reef, and want a complete photographic record of the study area (approximately 10,000 square meters). We also need to collect samples of unknown organisms for identification.
[ROPOS, Hercules, Tiburon, and some General Purpose ROVs could do this work. This is an opportunity to discuss the advantages and disadvantages of the different systems. You may want to ask what additional details about the mission would help in making the best choice.]

6. Briefly discuss the disadvantages of underwater robots compared to submersibles. The major drawback is that the human presence is lost, and this makes visual surveys and evaluations more difficult. Tethered robots also are constrained to some extent by their cabled connection to the support ship.

The Bridge Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click "Ocean Science Topics," then "Human Activities," then "Technology" for links to resources about submersibles, ROVs, and other technologies used in underwater exploration.

The "Me" Connection

Have students write a brief essay describing how robots are (or may be) of personal benefit.

Connections to Other Subjects

English/Language Arts, Life Science, Mathematics

Assessment

Reports and discussions in Steps 4 and 5 provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/06blacksea to keep up to date with the latest Aegean and Black Sea 2006 Expedition discoveries.

2. Build your own underwater robot! See books by Harry Bohm under "Resources."

Resources

NOAA Learning Objects

http://www.learningdemo.com/noaa/ – Click on the links to Lessons 1, 2, and 4 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Mid-Ocean Ridges, and Subduction Zones.

Other Relevant Lessons from the Ocean Exploration Program

What's Eating Titanic?

http://oceanexplorer.noaa.gov/explorations/04titanic/edu/media/Titanic04.Rusticles.pdf

(5 pages, 408k) (from the Titanic 2004 Expedition)

Focus: Biodeterioration processes (Physical Science/Biological Science)

In this activity, students will be able to describe three processes that contribute to the deterioration of the Titanic, and define and describe rusticles, explaining their contribution to biodeterioration. Students will also be able to explain how processes that oxidize iron in Titanic's hull differ from iron oxidation processes in shallow water.

Designing Tools for Ocean Exploration

http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9_12_l1.pdf

(13 pages, 496k) (from the 2002 Galapagos Rift Expedition)

Focus: Ocean Exploration

In this activity, students will understand the complexity of ocean exploration; learn about the technological applications and capabilities required for ocean exploration; discover the importance of teamwork in scientific research projects; and develop the abilities necessary for scientific inquiry.

Submersible Designer (4 pages, 452k) (from the 2002 Galapagos Rift Expedition)
[http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9-12_l4.pdf]

Focus: Deep Sea Submersibles

In this activity, students will understand that the physical features of water can be restrictive to movement; understand the importance of design in underwater vehicles by designing their own submersible; and understand how submersibles such as ALVIN and ABE, use energy, buoyancy, and gravity to enable them to move through the water.

Mapping the Canyon

http://oceanexplorer.noaa.gov/explorations/deepeast01/background/education/dehslessons2.pdf

(10 pages, 72k) (from the 2001 Deep East Expedition)

Focus: Hudson Canyon Bathymetry (Earth Science)

In this activity, students will be able to compare and contrast a topographic map to a bathymetric map; investigate the various ways in which bathymetric maps are made; and learn how to interpret a bathymetric map.

Finding the Way

http://oceanexplorer.noaa.gov/explorations/deepeast01/background/education/dehslessons4.pdf

(10 pages, 628k) (from the 2001 Deep East Expedition)

Focus: Underwater Navigation (Physical Science)

In this activity, students will describe how the compass, Global Positioning System (GPS), and sonar are used in underwater explorations; and understand how navigational tools can be used to determine positions and navigate in the underwater environment.

Other Resources and Links

http://oceanexplorer.noaa.gov/explorations/06blacksea – Web site for the Aegean and Black Sea 2006 Expedition

http://www.immersionpresents.org/ – Immersion Presents Web site; click on "Ancient Eruptions!" for more information about the Aegean and Black Sea 2006 Expedition, images, and educational activities

http://www.ngdc.noaa.gov/paleo/ctl/clihis10k.html –Timeline for last 10,000 years from NOAA's Paleoclimatology Web site

http://pubs.usgs.gov/pdf/planet.html – "This Dynamic Planet," map and explanatory text showing Earth's physiographic features, plate movements, and locations of volcanoes, earthquakes, and impact craters

http://disc.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/dead_zones.shtml – Web page from NASA about "Creeping Dead Zones," including SeaWIFS satellite imagery

http://news.nationalgeographic.com/news/2000/12/122800blacksea.html – National Geographic Web site, "Ballard Finds Traces of Ancient Habitation Beneath Black Sea"

http://blacksea.orlyonok.ru/blacksea.shtml – Web site of the Living Black Sea Marine Environmental Education Program in the Russian Federal Children Center Orlyonok

Friedrich, W. L.. 2000. Fire in the Sea. The Santorini Volcano: Natural History and the Legend of Atlantis. Translated by Alexander R. McBirney. Cambridge University Press. 258 pp.

Ryan, W. and W. Pitman. 1999. Noah's Flood: The New Scientific Discoveries About the Event That Changed History. Simon and Schuster. New York.

Yanko-Hombach, V. 2003. "Noah's Flood" and the late quaternary history of the Black Sea and its adjacent basins: A critical overview of the flood hypotheses. Paper presented at the Geological Society of America Annual Meeting, November 2–5, 2003, Seattle, WA (abstract available online at http://gsa.confex.com/gsa/2003AM/finalprogram/abstract_58733.htm).

http://ina.tamu.edu/ub_main.htm – Web site with information about the excavation of a Bronze Age shipwreck at Uluburun, Turkey

http://projectsx.dartmouth.edu/history/bronze_age/ – Dartmouth University Web site, "Prehistoric Archaeology of the Aegean," with texts, links to other online resources, and numerous bibliographic references

Bohm, H. and V. Jensen. 1998. Build Your Own Programmable Lego Submersible: Project: Sea Angel AUV (Autonomous Underwater Vehicle). Westcoast Words. 39 pages.

Bohm, H. 1997. Build your own underwater robot and other wet projects. Westcoast Words. 148 pages.

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in society

Content Standard G: History and Nature of Science
- Nature of science

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 6.
The ocean and humans are inextricably interconnected.
- *Fundamental Concept b.* From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
- *Fundamental Concept c*. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- *Fundamental Concept f*. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).
- *Fundamental Concept g.* Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.
- *Fundamental Concept a.* The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
- *Fundamental Concept b.* Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- *Fundamental Concept d.* New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- *Fundamental Concept f.* Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
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Student Handout

Underwater Robot Capability Survey

Name of Robotic Vehicle ____________________

Maximum Operating Depth ____________________

Tethered or Autonomous ____________________

Minimum Number of Crew Required for Operation ____________________

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Tools ____________________

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Special Capabilities or Advantages ____________________

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Other Details ____________________

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